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WIND-TUNNEL INVESTIGATION OF A LOW-DRAG AIRFOIL SECTION WITH A DOUBLE SLOTTED FLAP

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ADVANCE CONFIDENTIAL REPORT

WIND-TUNNEL INVESTIGATION OF A LOW-DRAG AIRFOIL SECTION WITH A DOUBLE SLOTTED FLAP

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SUMMARY

Tests of a 0.309-chord double-slotted flap on an NACA 65,3-118, a = 1.0 airfoil section have been made in the NACA two-dimensional low-turbulence tunnel and the NACA two-dimensional low-turbulence pressure tunnel. The purpose of the investigation was to determine the lift, drag, and pitching-moment characteristics for a range of flap deflections. The results indicate that the combination of a low-drag airfoil and a double-slotted flap of which the two parts moved as a single unit gave higher maximum lift coefficients than have been obtained with plain , split, or slotted flaps on low-drag airfoils. The maximum lift coefficients were almost as high as those obtained on conventional airfoils of about the same thickness with 0.40-chord venetian-blind and double-slotted flaps. The pitching moments were comparable to those obtained with other high lift devices on conventional airfoils for similar lift coefficients.

INTRODUCTION

The NACA has for some time been investigating airfoils equipped with high lift devices for the purpose of improving the performane characteristics of these airfoils. The results of tests of low-drag airfoils equipped with plain, split, or slotted flaps have been presented in reference 1. The results of references 2 and 3 show that, on conventional airfoils, the highest lifts have been obtained with large-chord venetian-blind and double-slotted flaps. The present investigation was made to determine the lift, drag, and pitching-moment characteristics of a low-drag airfoil with a double-slotted flap at various flap deflections. In addition, the optimum position for maximum lift and the flap path were to be found.

MODEL

The airfoil section tested, an NACA 65,3-118, a = 1.0 section, was equipped with a 0.309-chord double-slotted flap. The wing model, built of wood and reinforced with steel rods, had a 24-inch chord and was painted and sanded to produce aerodynamically smooth surfaces. The airfoil ordinates are presented in table I and a sketch of the model is shown in figure 1.

The double-slotted flap was made of aluminum and consisted of two parts. The forward portion, designated the fore flap, was separated from the main part, designated the rear flap, by a secondary slot. The ordinates for the fore flap and rear flap are presented in table II. The double-slotted flap operated as a single unit, with no relative motion between the fore flap and the rear flap. The operating mechanism and construction was similar to that of an ordinary slotted flap. The long lower lip completely closed all gaps and slots when the double-slotted flap was retracted. The flap arrangement and pivot points are shown in figure 1 for the flap retracted and deflected 65°. The contour of the airfoil cut-out may be obtained by following the flap outline along the flap path.

TEST PROCEDURE[1]

Tests were made of the model in the NACA two-dimensional low-turbulence tunnel and the NACA two-dimensional low-turbulence pressure tunnel. Section lift coefficients were obtained by measurement of the lift reaction on the floor and ceiling of the tunnel, and section drag coefficients were obtained by the wake-survey method. No drag measurements were made for flap deflections δ_f above 35° because of considerable spanwise variation of drag. Pitching-moment coefficients $c_{m_{c/4}}$ were measured by means of a calibrated torque rod and were taken about the quarter-chord point of the airfoil.

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[1]At the time this report was originally published, some of the corrections required for reducing the test data to free-air conditions had not been determined. The values of section lift coefficient c_l (figs. 2 to 5) should be corrected by the equation

$$c_{l_{(corrected)}} = 0.965c_l + 0.033c_{l_{\alpha_0=-1^\circ}}$$

where $c_{l_{\alpha_0=-1^\circ}}$ is the uncorrected section lift coefficient at section angle of attack of -1°.

Preliminary tests were made to determine the best position of the fore flap relative to the rear flap on the basis of maximum section lift coefficient $c_{l_{max}}$ obtained at a flap deflection of 65°. This survey of fore-flap position was limited to those positions at which the flap could be retracted without having the fore flap protrude beyond the airfoil surface. The rear flap and fore flap were then fixed in the best relative position and the procedure was repeated for the unit. The flap path was so chosen that, at 45° deflection, the flap was in a position at which both slots were effective and, at 65° deflection, the flap was in a position at which maximum lift was reached. One pivot point was used for flap deflections up to 45°; whereas another pivot point was used for deflections from 45° to 65°. (See fig. 1.)

Lift, drag, and pitching moments were obtained for flap deflections ranging from 0° to 65°. Lift and drag data were obtained at a Reynolds number of 6,000,000 and pitching-moment data were obtained at a Reynolds number of 4,500,000. Scale effect on maximum lift was found for a range of Reynolds numbers from 4,000,000 to 9,000,000.

RESULTS AND DISCUSSION

The results of the flap-position survey of the double-slotted flap for the flap position that would give maximum lift are presented in figure 2. Section lift characteristics for the combination with the flap deflected through a range of angles from 0° to 65° are presented in figure 3 for a Reynolds number of approximately 6,000,000. The maximum section lift coefficient obtained was 3.40 at a flap deflection of 65°, at which an increment in maximum lift coefficient of about 1.79 was obtained. Complete data for only one double-slotted flap are presented, but previous unpublished tests have shown that a decrease in chord of the fore flap gave a decrease in the maximum lift obtainable. The scale effect on maximum lift coefficient was found to be negligible over the range of Reynolds numbers tested. The small jogs in the lift curves, which appear for the 0° and 10° flap deflections, do not occur at the higher deflections.

Section drag characteristics for the combination for flap deflections from 0° to 35° are presented in figure 4. These tests were run at a Reynolds number of approximately 6,000,000. For the flap retracted and deflected 10°, fairly low drag coefficients are obtainable over a range of lift coefficients from about -0.2 to 0.8, which includes the normal high-speed and cruising-flight conditions. The relatively low drag obtained for the 35° deflection is probably due to the establishment of smooth flow through the main slot. At a flap deflection of 35°, a section lift-drag of approximately 170 may be obtained at a lift coefficient of about 1.6.

For deflections above 35° no drag measurements were taken, but visual observation of the wake-survey manometer indicated that the drags were not excessive. The high lifts with comparatively low drags are the result of unstalled flows over the flap, as was indicated by tuft surveys which showed no separation of the flow over the flap up to a deflection of 65°.

Section pitching-moment characteristics for the airfoil-flap combination for all flap deflections tested are presented in figure 5. Although pitching-moment coefficients were measured at a Reynolds number of 4,500,000, little change in these characteristics is expected for other Reynolds numbers because previous tests of slotted flaps on low-drag wings (reference 1) have shown that, for lifts below maximum, scale effect on pitching moments is very small.

The double-slotted flap tested gave a lift coefficient higher than those obtained on the low-drag airfoils with plain, split, or slotted flaps reported in reference 1. The 0.309-chord double-slotted flap tested on an 18-percent-thick low-drag airfoil gave lifts almost as high as the lifts obtained on conventional 12- and 21-percent-thick airfoils with 0.40-chord venetian blind and double-slotted flaps (references 2 and 3). The increment in maximum lift was 1.79 for the low-drag airfoil and approximately 2.00 for the conventional airfoils. With the flap retracted, the double-slotted flap tested gave plain-wing section drag coefficients without the need of folding doors to close gaps and slots. The pitching moments shown in figure 5 are of about the same magnitude as pitching moments obtained for the 0.40-chord venetian-blind and the double-slotted flaps of references 2 and 3.

CONCLUSIONS

From the results of the tests of a 0.309-chord double-slotted flap on an NACA 65,3-118, a = 1.0 airfoil, the following conclusions were reached:

1. The double-slotted flap tested gave lift coefficients higher than those that have been obtained on NACA

low-drag airfoils with plain, split, or slotted flaps and did not affect the low-drag characteristics of the wing with the flap retracted.

2. The combination tested also offered low drag and moderate lift for the cruising condition and fairly low drag and high lift for take-off and climb conditions.

3. The lift coefficients obtained with the 0.309-chord double-slotted flap were almost as high as those obtained with larger-chord venetian-blind and double-slotted flaps on conventional airfoils of approximately the same thickness as the low-drag airfoil tested.

4. The high lift coefficients obtained with the 0.309-chord double-slotted flap were accompanied by high pitching moments, which were comparable to those obtained with other high lift devices giving similar maximum lift coefficients.

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REFERENCES

1. Jacobs, Eastman N., Abbott, Ira H., and Davidson, Milton: Preliminary Low-Drag-Airfoil and Flap Data from Tests at Large Reynolds Numbers and Low Turbulence, and Supplement. NACA A.C.R., March 1942.

2. Wenzinger, Carl J., and Harris, Thomas A.: Preliminary Wind-Tunnel Investigation of an N.A.C.A. 23012 Airfoil with Various Arrangements of Venetian-Blind Flaps. NACA Rep. No. 689, 1940.

3. Harris, Thomas A., and Recant, Isidore G.: Wind-Tunnel Investigation of NACA 23012, 23021, and 23030 Airfoils Equipped with 40-Percent-Chord Double Slotted Flaps. NACA Rep. No. 723, 1941.

TABLE I

ORDINATES FOR THE NACA 65,3-118, a = 1.0, AIRFOIL

[Station and ordinates in percent of airfoil chord]

Upper surface		Lower surface	
Station	Ordinate	Station	Ordinate
0	0	0	0
.444	1.348	.556	-1.298
.688	1.633	.812	-1.563
1.180	2.057	1.320	-1.949
2.421	2.820	2.579	-2.634
4.910	3.988	5.090	-3.672
7.406	4.912	7.594	-4.488
9.905	5.681	10.095	-5.165
14.909	6.903	15.091	-6.231
19.918	7.832	20.082	-7.036
24.929	8.541	25.071	-7.645
29.942	9.054	30.058	-8.082
34.956	9.383	35.044	-8.353
39.971	9.526	40.029	-8.454
44.986	9.464	45.014	-8.368
50.000	9.145	50.000	-8.041
55.013	8.593	54.987	-7.497
60.024	7.853	59.976	-6.781
65.032	6.965	64.968	-5.935
70.037	5.972	69.963	-5.000
75.039	4.904	74.961	-4.008
80.037	3.788	79.963	-2.992
85.032	2.661	84.968	-1.989
90.023	1.582	89.977	-1.066
95.012	.650	94.988	-.334
100.000	0	100.000	0

Leading edge radius = 1.92

Slope = 0.042

TABLE II

ORDINATES FOR A 0.309-CHORD DOUBLE-SLOTTED FLAP ON

AN NACA 65,3-118, a = 1.0 AIRFOIL

[Station and ordinates in percent of airfoil chord]

Fore flap			Rear flap		
Station	Upper surface	Lower surface	Station	Upper surface	Lower surface
69.083	-3.125	-------	75.563	-1.250	-------
[a]69.104	-3.542	-------	75.833	-.104	-2.292
69.167	-2.417	-3.729	76.250	.500	-2.729
69.375	-1.792	-4.104	77.083	1.167	-3.146
69.583	-1.458	-4.333	78.125	1.771	-3.250
70.000	-.708	-4.500	79.167	2.188	-3.167
70.833	.188	-4.438	81.250	2.583	-2.729
72.083	1.050	-2.708	83.333	2.583	-2.292
73.333	1.604	.292	85.417	2.425	-1.867
74.583	1.958	1.438	87.500	2.104	-1.467
75.208	2.125	1.771	90.023	1.582	-1.058
75.833	2.250	2.042	95.012	.650	-.334
76.458	2.375	2.292	100.000	0	0
76.875	2.438	2.417			

[a]Reference point for fig. 2

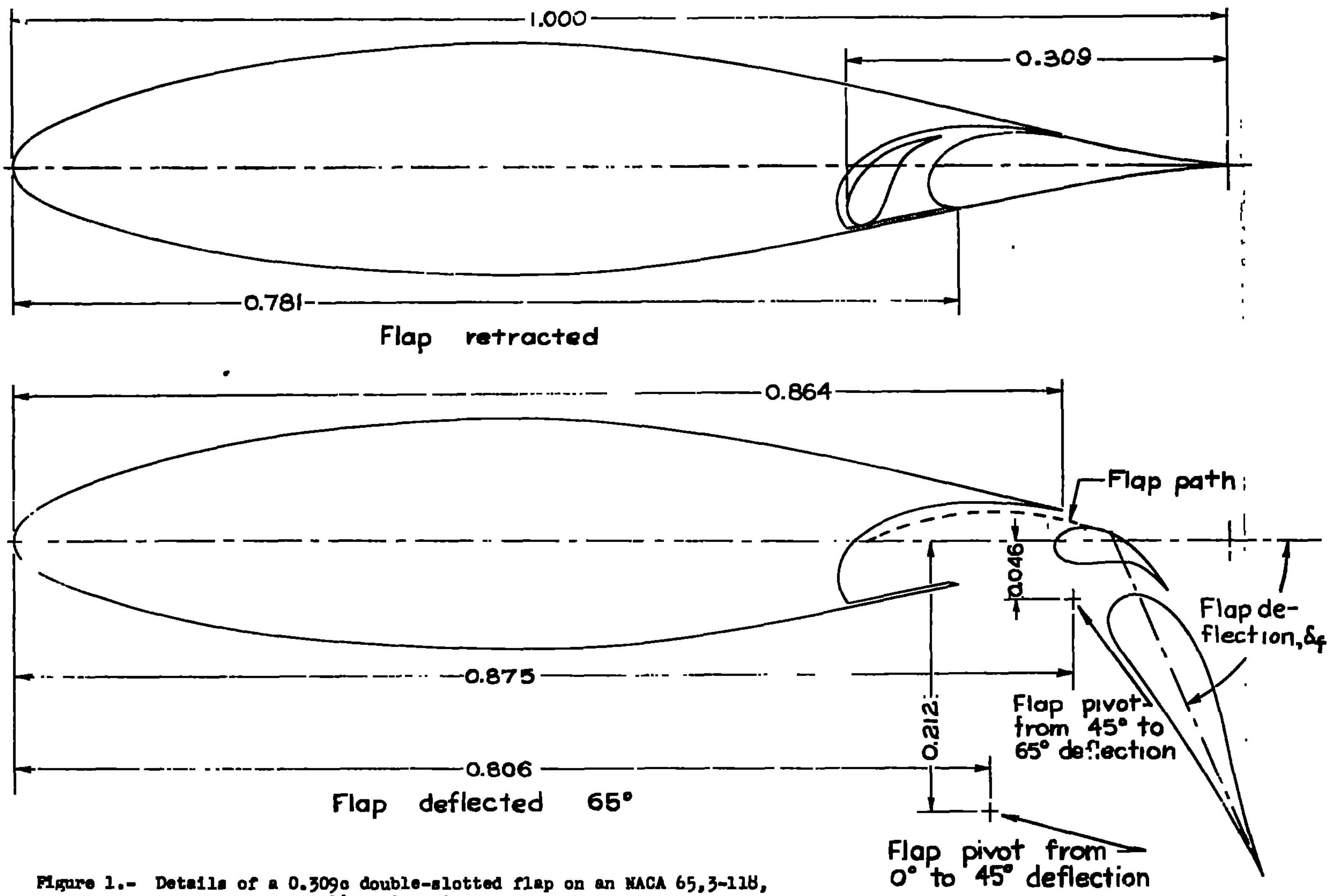


Figure 1.- Details of a 0.309c double-slotted flap on an NACA 65,3-118, a = 1.0 airfoil. Dimensions in fraction of chord.

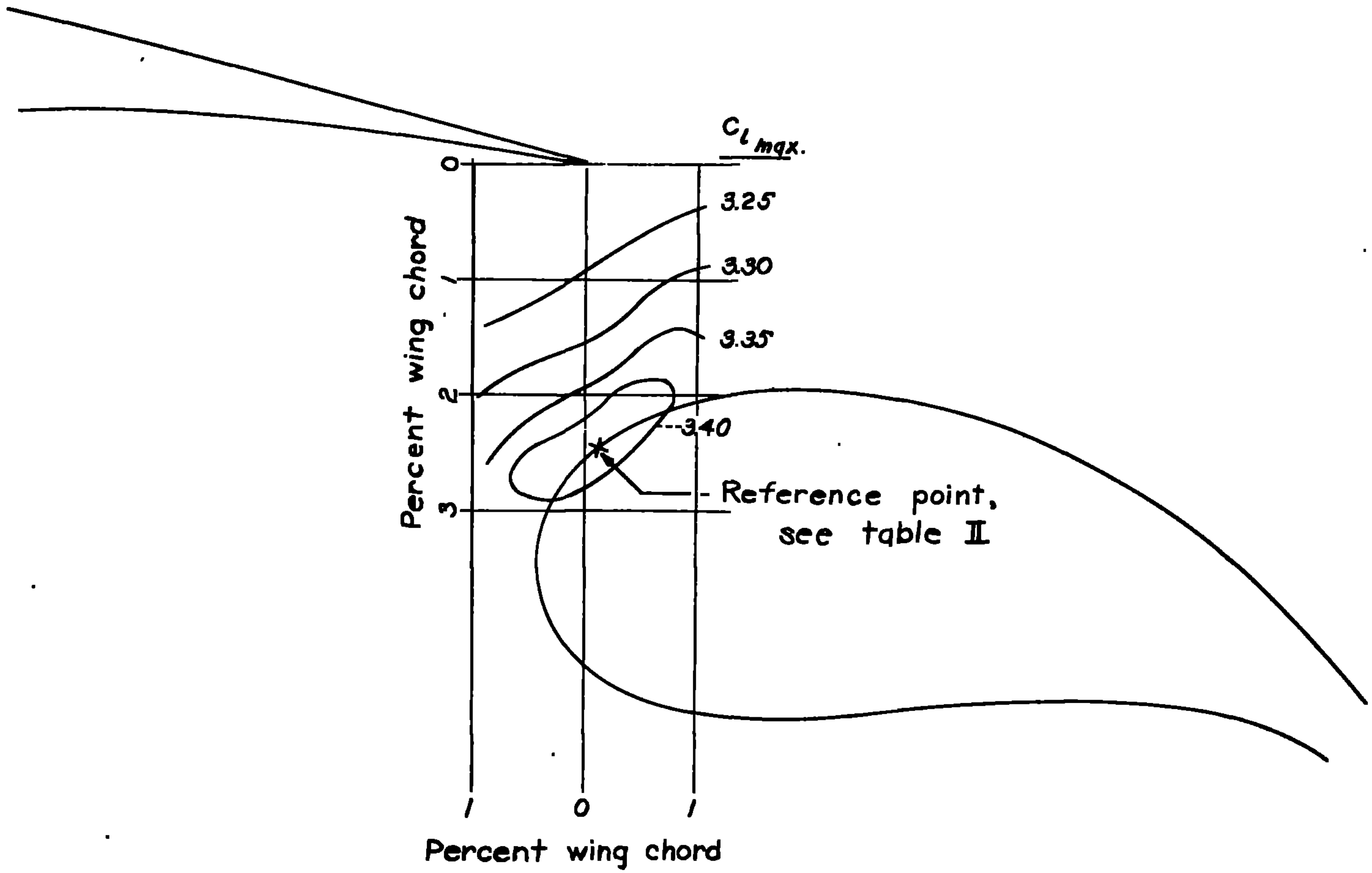


Figure 2.- Contours of flap location for $c_{l_{max}}$ for a 0.309c double-slotted flap on an NACA 65,3-118, a = 1.0 airfoil; δ_f, 65°.

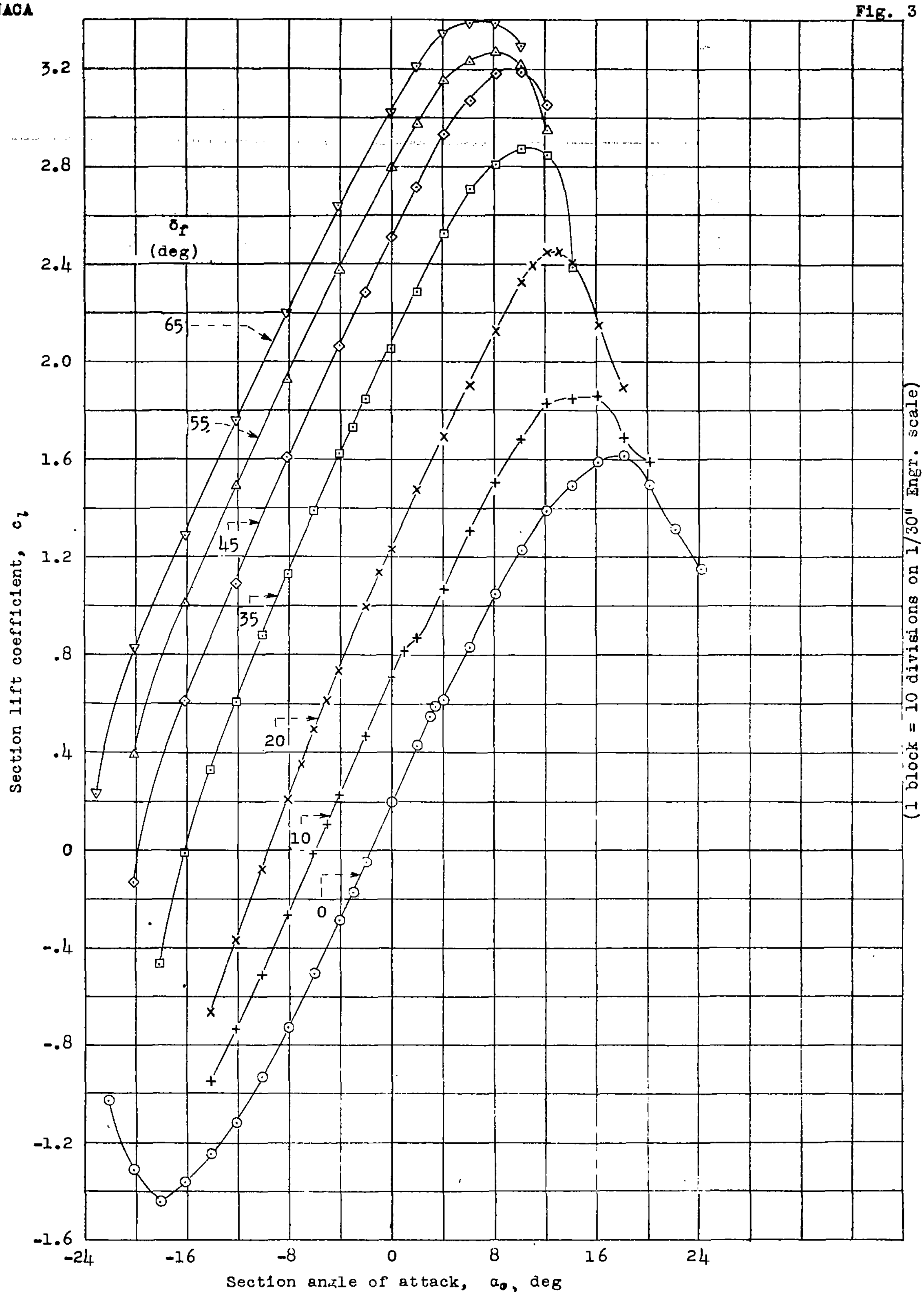


Figure 3.- Section lift characteristics of an NACA 65,3-118, a = 1.0 airfoil with a 0.309c double-slotted flap at various deflections; R, 6,000,000 (approximately). Tests, TDT 399, 435, 452.

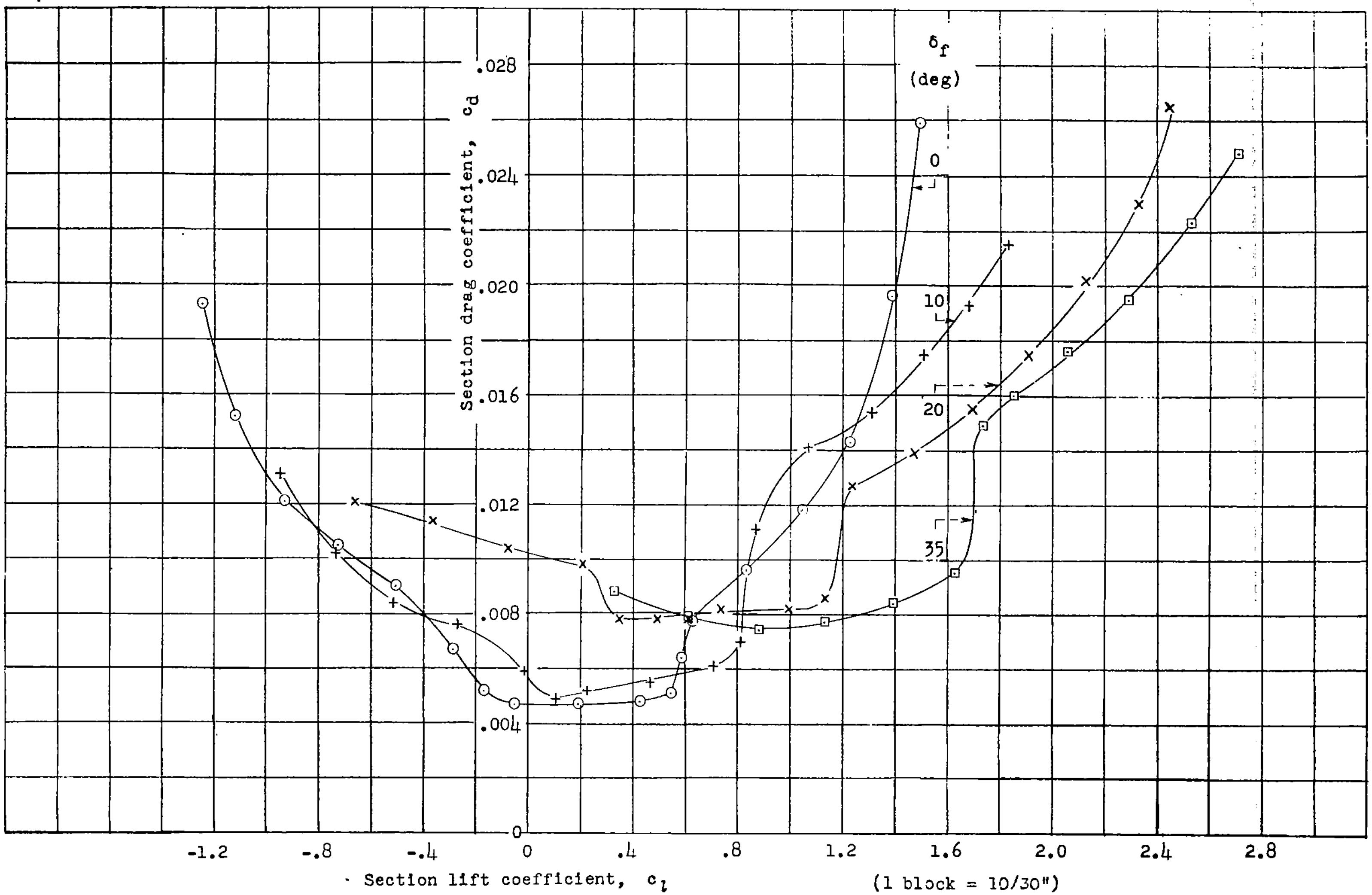
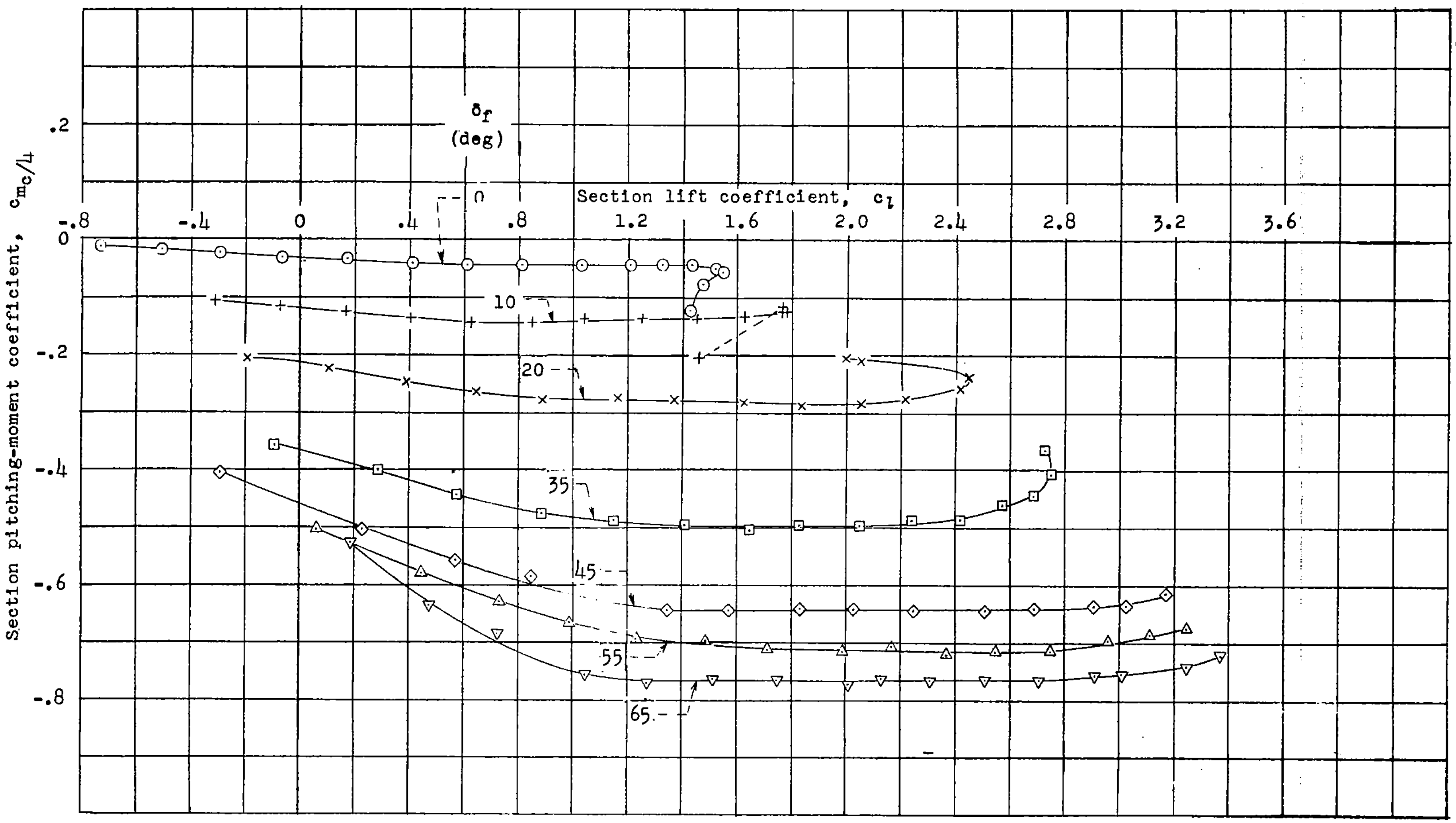


Figure 4.- Section drag characteristics of an NACA 65,3-118, a = 1.0 airfoil with a 0.309c double-slotted flap at four deflections; R, 6,000,000 (approximately). Tests, TDT 399, 435.



(1 block = 10/30")

Figure 5.- Pitching-moment characteristics of an NACA 65,3-118, a = 1.0 airfoil with a 0.309c double-slotted flap at various deflections; R, 4,500,000 (approximately). Tests, TDT 460, 462.

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Fig. 5